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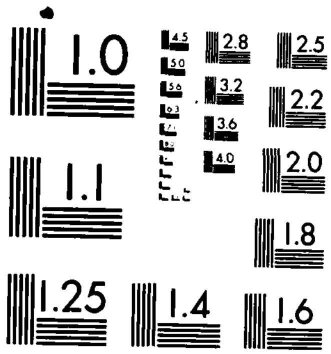

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The research of four principal investigators as well as the operations of the Center for Stochastic Processes was supported by this grant. Substantial research progress was made in stochastic processes and in statistical estimation and inference. More than 135 journal articles were published or accepted for publication. The work of 19 visiting scholars was supported. Keywords: -

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ANNUAL AND FINAL SCIENTIFIC REPORT

Air Force Office of Scientific Research Grant AFOSR F49620 82 C 0009

Period: 1 November 1981 through 31 August 1985

Title: Research in Stochastic Processes

Co-Prinicipal Investigators: Professor Stamatis Cambanis

Professor Raymond J. Carroll

Professor Gopinath Kallianpur

Professor M. Ross Leadbetter

The material on pages 1 to 52 describes the research effort during the period 1 September 1984 through 31 August 1985, and the material on pages 53 to 77 is the final report.

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CONTENTS

ANNUAL REPORT

1 September 1984 - 31 August 1985

SUMMARY OF RESEARCH ACTIVITY

Research was conducted and directed in the area of stochastic processes by three of the Principal Investigators, S. Cambanis, G. Kallianpur, and M.R. Leadbetter, and their associates, and in statistical estimation and inference by R.J. Carroll and co-workers. A summary of the main areas of research activity follows for each Principal Investigator and co-workers. More detailed descriptions of the work of all participants is given in the main body of the report.

S. Cambanis. Non-Gaussian signal processing: innovations and Wold decompositions of stable signals; prediction of harmonizable stable signals; detection of sure signals in stable noise and discrimination between stable signals; random integral representations of stable processes with paths in Banach spaces; moment inequalities for stable integrals; representation of the classical limit laws by random integrals. Digital processing of analog signals: performance of discrete-time predictors of continuous-time processes; estimation of random integrals from noisy observations: sampling designs and their performance. Nonlinear signals and systems: stochastic integration by series of Wiener integrals.

G. Kallianpur. Nonlinear filtering, interpolation and prediction theory. Estimation of continuous time Markov processes in a finitely additive white noise model. Linear stochastic differential equations (SDE's) with applications to neurophysiology and chemical reactions. Fluctuations near homogeneous states of chemical reactions with diffusion. Nuclear space valued SDE models for spatially extended neurons: linear and nonlinear models, continuous and discontinuous. Product stochastic measures, multiple stochastic integrals and their extensions to

nuclear space valued processes. Stationary random fields: spectral analysis, moving average representation, prediction and angle.

M.R. Leadbetter. Extremal theory: extremes and local dependence in stationary sequences; extremes in Markov and moving average sequences, continuous parameter stochastic processes, multivariate extremal theory. Point processes associated with extremal theory: exceedance point process and compound Poisson limit theorems, "complete convergence" and the asymptotic behavior of order statistics. Dependence structure of stochastic sequences: basic properties and relationships among forms of mixing condition. Function estimation: probability density estimation for stationary sequences and processes.

R.J. Carroll. Heteroscedasticity and weighted least squares: the effect of estimating weights; weighted regression when there are outliers. Data Transformation: using transformations in nonlinear regression. Measurement error models: the effect of ignoring small measurement errors in precision instrument calibration; the distribution of least squares when there is measurement error. Robustness: robust regression for generalized linear models. Survival Analysis: models for transient state behavior, some diagnostics for outliers in accelerated life testing. Nonparametric density and regression function estimation: the amount of noise inherent in bandwidth selection, selection of regression variables and rates of convergence. Bootstrapping: bootstrap and confidence intervals, and the required number of bootstrap simulations.

RESEARCH IN STOCHASTIC PROCESSES

STAMATIS CAMBANIS

The work briefly described here was developed in connection with problems arising from and related to the statistical communication theory and the analysis of stochastic signals and systems, and falls into the following two categories:

I. Non-Gaussian signal processing,

II. Digital processing of analog signals.

Items 1 to 3 belong to category I. Item 1 represents contuing work with Drs. Hardin and Weron; it is the completion of our work on innovations in the discrete case; the much more complex study of innovation in the continuous-time case is currently in progress. Item 2 is joint work with Dr. Miamee. Item 3 describes some of the work in progress with Mr. Marques, a Ph.D. student; a full description will be in the next reporting period. Items 4 to 6 belong to category II. Item 4 is joint work with Dr. Bucklew and substantial new material is being added to it in the course of revision for journal publication. Item 5 represents continuing work with Dr. Masry, which was completed during the current reporting period. Item 6 is a preliminary description of work in progress with Mr. Benhenni, a Ph.D. student, on several important questions in sampling designs, motivated by the work in Items 4 and 5.

1 <u>Innovations and Wold decompositions of stable sequences</u> [1]

For symmetric stable sequences, notions of innovation and of Wold decomposition are introduced and characterized, and their ramifications in prediction theory are discussed. As the usual covariance orthogonality is inapplicable, the non-symmetric James covariation orthogonality is used, thus leading to right and left innovations and Wold decompositions, which are related to regression prediction and least p^{th} moment prediction, respectively. Independent innovations and Wold decomposition are also characterized; and several

examples illustrating the various decompositions are presented.

2. On prediction of harmonizable stable processes [2]

Spectral and time domain criteria for a harmonizable stable process to be regular are given, which provide an orthogonal moving average representation. Also criteria for such processes to have linear predictor filters are obtained; these include the positivity of the distance and of the angle between past and future. In the process, the notion of angle between isotropic complex stable random variables is introduced and studied.

3. Detection of sure signals in stable noise and discrimination between stable processes [3]

In detecting a deterministic signal in Gaussian noise, its reproducing kernel Hilbert space is crucial. If the signal does not belong to it, it can be detected with probability one and the detection problem is called singular. And if it belongs to it, the distributions of signal plus noise and of noise alone are equivalent, the detection problem is called regular, and most criteria lead to a likelihood ratio test. In the non-Gaussian stable case a moment function space is introduced which has some (but by no means all) of the properties the reproducing kernel Hilbert space has in the Gaussian case. Specifically a sure signal which does not belong to the noise moment function space, can be detected with probability one. Thus if the signal detection problem is regular, the signal has to belong to the noise moment function space. However the class of signals whose detection is regular can be as large as the entire noise moment function space (e.g. sub-Gaussian noise, i.i.d. noise sequence) or as small as empty (e.g. noise with independent increments, harmonizable noise). The case of further specific classes of stable noises is under study.

The discrimination between two stable processes is singular whenever their moment function spaces are not identical. This should lead to a perfect

discrimination between stable processes with different index of stability. The case where their moment function spaces coincide requires further study, with emphasis on special classes of stable processes.

4. Estimating random integrals from noisy observations: Sampling designs and their performance [4]

The problem of estimating a weighted average of a random process from noisy observations at a finite number of sampling points is considered. The performance of sampling designs with optimal or suboptimal, but easily computable, estimator coefficients is studied. Several examples and special cases are studied including additive independent noise, nonlinear distortion with noise, and quantization noise.

5. Performance of discrete-time predictors of continuous-time processes [5]

We study the asymptotic performance of linear predictors of continuous-time stationary processes from observations at n sampling instants of a fixed observation interval. We consider both optimal and simpler choices of predictor coefficients; and uniform sampling, as well as nonuniform sampling tailored to the statistics of the process under prediction. We concentrate on stationary processes with rational spectral densities and numerical examples, depicting small sample size performance in addition to asymptotics, are given for cases with no and with one quadratic mean derivative.

6. Problems in sampling designs

A deeper connection between quadrature formulae in integral approximation theory and the approximation of integrals of random processes is under study. When the process has no quadratic mean derivative, the rectangular rule of integral approximation leads to an asymptotically optimal sampling design. When the process has exactly one quadratic mean derivative, the trapezoidal rule is shown in [5] to have the same rate of convergence as the optimal estimator, but

larger asymptotic constant. Further appropriate versions of the trapezoidal rule lead to a smaller asymptotic constant and we are currently studying the extent to which this reduction can be pursued by judicious adjustment of the trapezoidal rule, in order to determine whether there exist asymptoticaly optimal designs based on the trapezoidal rule.

Further problems under investigation include the study of the rate of convergence of the optimal predictor in [5], where a conjecture has been backed by numerical computation; and the development of asymptotically optimal designs when the random processes involved have fractional, rather than integer, number of quadratic mean derivatives - an important case which arose in [4] in the course of assessing the effect of unavoidable nonlinearities, such as quantizers.

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2. S. Cambanis and A.G. Miamee, On prediction of harmonizable stable processes, Center for Stochastic Processes Technical Report No. 110, July 85.

3. M. Marques, A study of equivalence and singularity of stable processes, in preparation.

4. J.A. Bucklew and S. Cambanis, Estimating random integrals from noisy observations: Sampling designs and their performance, Center for Stochastic Processes Technical Report No. 86, December 84.

5. S. Cambanis and E. Masry, Performance of discrete-time predictors of continuous-time processes, Center for Stochastic Processes Technical Report No. 123, Nov. 85.

GOPINATH KALLIANPUR

1. Filtering, interpolation and prediction theory [1,2]

Work on this subject, initiating a new approach based on finitely additive white noise, has been continuing for the last three years. We (R.L. Karandikar and I) have been writing a monograph on White Noise Calculus and Filtering [1], including the research so far done as well as continuing new work. Included in the latter are (a) the solution of the filtering problem for Hilbert space valued, Markov signal processes and the derivation of consistency results for the corresponding stochastic calculus theory; (b) the problem of non-white Gaussian noise. The second question has been partially resolved (in collaboration with R.L. Karandikar and H. Hucke) but a satisfactory solution awaits completion of the proof of the Bayes formula.

The Monograph itself will include a treatment of the smoothing, prediction and filtering problems when the signal is (i) a diffusion with boundary and (ii) the solution of a general Skorokhod-type stochastic differential equation. The work on the latter topics will incorporate results obtained by H. Hucke (my Ph.D. student) in his recent thesis [2].

2. Nuclear space valued stochastic differential equation (SDE) models for spatially extended neurons [3,4,5]

(i) In [3] we extended work of G. Kallianpur and R. Wolpert on the Poisson driven, as well as the Ornstein-Uhlenbeck, nuclear space valued SDE's under more general assumptions. Some recent heuristic results of Wan and Tuckwell are included as special cases in this rigorous treatment. More general weak convergence results are also obtained.

(ii) To account for the difficult nonlinear problems arising in more realistic descriptions of neuronal behavior, a theory is being developed along two

different directions:

(a) In collaboration with R. Wolpert [4], the existence of solutions of nonlinear nuclear space valued diffusions has been established. The conditions (involving coercivity and growth conditions among others) are weaker and significantly different from those used in the study of Banach space valued SDE's by Krylov and Rozovskii. Galerkin approximation techniques are used. A monotonicity condition together with a Yamada-Watanabe type result yields uniqueness of the strong solution. The question of uniqueness of the weak solution (or of the martingale problem) is still open.

(b) Work similar to (a) but with Poisson driven (more generally, with processes of independent increments) nuclear space valued SDE's is in progress, jointly with S. Ramasubramanian [5]. Existence of a solution has been established. An interesting application is to the problem of "reversal potentials" in the behavior of neurons. The possibility of obtaining a diffusion approximation (using results of (a)) for the reversal potential problem is now being investigated. As in (a) the uniqueness of the martingale problem remains to be established.

3. Work on the Feynman integral

The investigation of nuclear space valued SDE's in connection with neurophysiological problems led to the idea of using them to obtain a representation of the solution of the so-called Schwinger equation (terminology apparently due to Gaveau) in Quantum Field Theory. The latter equation (more properly the associated unitary group) deals with a quantum mechanical system of an infinite number of harmonic oscillators. We hope to obtain a more satisfactory as well as a rigorous solution in the form of a Feynman "path integral".

4. Second Order Stationary Random Fields [6]

The main object of this research is to obtain spectral criteria for the

concepts of horizontally and vertically purely nondeterministic, second order stationary random fields. These concepts were introduced by Kallianpur and Mandrekar (1983) and were studied in the time domain only. The present approach has a close relationship to some early work of Chiang (Theor. Probability Appl., 2, 1957). Also, spectral conditions for the different types of moving average schemes are derived, and the four-fold "Wold-Halmos" type decomposition is examined from this point of view.

Ph.D. theses under G. Kallianpur

S.K. Christensen. Linear Stochastic Differential Equations on the Dual of a Countably Hilbert Nuclear Space with Applications to Neurophysiology [7,3]

Properties of the Ornstein-Uhlenbeck (OU) process on the dual of a nuclear space are derived; stationarity and existence of a unique invariant measure are proved, a Radon-Nikodym derivative is exhibited and the OU process is investiaged for flicker noise.

The existence and uniqueness of solutions to linear stochastic differential equations on the dual of a nuclear space are established, and general conditions for the weak convergence of solutions in Skorohod space are given. Moreover, solutions are shown to be CADLAG semimartingales (for appropriate initial conditions). The results are applicable in solving stochastic partial differential equations.

These results are applied to giving a rigorous representation and solution of models in neurophysiology, and to deriving explicit results for the weak convergence of these solutions.

H.P. Hucke. Estimation of continuous time Markov processes in a finitely additive white noise model [2]

The nonlinear filtering and prediction problems are solved for a wide variety

of continuous time Markov signal processes using the finitely additive white noise model of Kallianpur and Karandikar (1983). This model has already been successfully applied to the nonlinear filtering problem for diffusion processes and situations involving infinite-dimensional observation processes by Kallianpur and Karandikar (1983, 1984).

The results of this thesis show that also for the cases of jump type Markov processes, Lévy processes and diffusion processes with boundaries, the filtering and prediction problems can be solved by finding the unique solution to an initial-value problem for a differential equation. Further the continuity properties of the estimates in the white noise model are investigated and it is shown that they are robust in the sense in which this term is used in nonlinear filtering theory. As a generalization of the white noise model, a particular kind of non-white noise model is introduced and the filtering problem for multi-dimensional diffusion processes is solved in this setup.

V.M. Perez-Abreu C., <u>Product Stochastic Measures, Multiple Stochastic Integrals and their Extensions to Nuclear Space Valued Processes</u> [8,9]

A theory of L^2-valued product stochastic measures of non-identically distributed L^2-independently scattered measures is developed using concepts of symmetric tensor product Hilbert spaces. Applying the theory of vector valued measures, multiple stochastic integrals with respect to the product stochastic measures are constructed. A clear relationship between the theories of vector valued measures and multiple stochastic integrals is established. This work is related to the work by Engel (1982), which gives a different approach to the construction of product stochastic measures. The two approaches are compared.

The second part of the work deals with multiple Wiener integrals and nonlinear functionals of a Wiener process with values in the dual of a countably Hilbert nuclear space. The Wiener decomposition of the space of nonlinear

functionals is obtained as an inductive limit of appropriate Hilbert spaces. It is shown that every nonlinear functional admits an expansion in terms of multiple Wiener integrals in one of these Hilbert spaces and can be represented as an operator valued stochastic integral of the Itô type.

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4. G. Kallianpur and R. Wolpert, Weak convergence of solutions of nonlinear stochastic differential equations with applications to nonlinear neuronal models: Nonlinear diffusions, in preparation.

5. G. Kallianpur and S. Ramasubramanian, Weak convergence of Poisson driven stochastic differential equations with applications to nonlinear neuronal models, in preparation.

6. G. Kallianpur, A. Miamee and H. Niemi, Spectral analysis of weakly stationary random fields: Moving average representations, in preparation.

7. S.K. Christensen, Linear stochastic differential equations on the dual of a countably Hilbert nuclear space with applications to neurophysiology, Center for Stochastic Processes Technical Report No. 104, June 85.

8. V. Perez-Abreu C., Product stochastic measures, multiple stochastic integrals and their extensions to nuclear space valued processes, Center for Stochastic Processes Technical Report No. 107, June 85.

9. V. Perez-Abreu C., Product stochastic measures, Center for Stochastic Processes Technical Report No. 118, Oct. 85.

M.R. LEADBETTER

During this reporting period work continued or was initiated in the following main areas: (1) point processes and random measures associated with extremal theory for stochastic sequences (2) structural point process theory (3) Extremes of continuous parameter processes, and (4) function estimation for stationary processes. The work in each is described below.

1. Point processes and random measures in extremal theory.

Research continued into the structure of high level exceedances by a stationary sequence and properties of point processes of such exceedances. The possible point process limits (as the level increases) were characterized as the class of compound Poisson Processes and sufficient conditions obtained for such convergence. This work was reported in [1], submitted to Zeit. Wahr. verw. Geb. for journal publication) and [2].

This research required that the exceedance levels considered should tend to infinity in an appropriately normalized way. While such cases are the most important it is also of interest to consider rather arbitrary levels, and also to look for normalizations of the point processes which lead to non degenerate limits. These limits need not be point processes but may have a general random measure structure. Results obtained thus far show that it is possible to characterize the possible limits, and that the Compound Poisson limits obtained earlier form an important class, but a subclass of those possible in the more general random measure context.

Work has begun on corresponding results in so-called "complete" convergence; that is random measure limits for the two-dimensional point process formed by plotting the values of a stationary sequence in the plane (after suitable normalizations). Such results summarize the joint asymptotic behavior of

arbitrary numbers of extreme order statistics.

Work is nearing completion on a Special Invited Paper ([3]) for the Annals of Probability. This paper (with H. Rootzén) surveys the field of dependent extremal theory, emphasizing the role of point process methods, and results obtained (primarily under this contract) since the publication of the volume [4].

2. Structural point process theory.

Some effort has continued in the development of a structural theory for point processes and random measures, relying on a measure-theoretic rather than a topological basis as far as possible. Results obtained thus far primarily involve representations of random measures (in terms of discrete components and atoms) on spaces with measure-theoretic separation properties. This work is continuing.

3. Extremes of continuous parameter processes.

Much of the theory of extremes for continuous parameter stationary processes has been developed in previous contract periods, so that a satisfying basic framework now exists. The effort in the present period has been to obtain point process results in the continuous parameter case, paralleling those in discrete time. Two situations have been found to be of particular interest: (a) where high local dependence occurs causing clustering of high-level upcrossing and (b) where very low local dependence causes infinitely many upcrossings due to sample path irregularity. This work is continuing.

4. Function estimation for stationary processes.

Further research was conducted on the problem of estimating probability density functions from stationary time series and continuous parameter processes. In particular improved results were obtained for convergence of the estimates to normality, in both discrete and continuous contexts. This work was reported in a revision of [5] which will appear as the journal publication [6].

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5. J. Castellana and M.R. Leadbetter, On smoothed probability density estimation for stationary sequences, Center for Stochastic Processes Technical Report No. 50, Dec. 83.

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ROBERT J. ADLER

Dr. Adler is pursuing his work on extrema of random fields and the relationships between Markov processes and Gaussian fields. The folowing report has been completed.

Extrema and level crossings of χ^2 processes [1]

We study the sample path behaviour of χ^2 processes in the neighbourhood of their level crossings and extrema via the development of Slepian model processes. The results, aside from being of particular interest in the study of χ^2 processes, have a general interest insofar as they indicate which properties of Gaussian processes (which have been heavily researched in this regard) are mirrored or lost when the assumption of normality is not made. We place particular emphasis on the behaviour of χ^2 processes at both high and low levels, these being of considerable practical importance. We also extend previous results on the asymptotic Poisson form of the point process of high maxima to include also low minima (which are in a different domain of attraction) thus closing a gap in the theory of χ^2 processes.

References

1. M. Aronowich and R.J. Adler, Extrema and level crossings of χ^2 processes, Center for Stochastic Processes Technical Report No. 113, Aug. 85.

RICHARD BRADLEY

An essential component of stochastic process theory is the understanding of the dependence structure involved. In particular long range dependence restrictions can induce features of classical "i.i.d." theory on models involving dependence. One of the activities under the contract is the investigation of various types of dependence restrictions and a delineation of their appropriate areas of use.

A substantial effort involving so-called "mixing assumptions" has been undertaken by Dr. Bradley and co-workers in this reporting period. "Strong" mixing conditions have been considered and an up-to-date account of their known properties given in [2]. Equivalences and relationships between a variety of dependence conditions were studied (in conjunction with W. Bryc and S. Janson) and these results are reported in [3]. Throughout the work attention has been paid to illustrative examples which lead to further understanding of dependence structure. In particular light is shed on certain aspects of strong mixing by consideration of certain "bilaterally deterministic" ρ-mixing stationary sequences. This is described in [1].

A study was also made of the use of combinations of mixing assumptions. It was found that this may facilitate the establishing of certain weak and strong invariance principles for strictly stationary sequences [4].

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2. R.C. Bradley, Basic properties of strong mixing conditions, Center for Stochastic Processes Technical Report No. 102, June 85.

3. R.C. Bradley, W. Bryc and S. Janson, Remarks on the foundations of measures of dependence, Center for Stochastic Processes Technical Report No. 105.

4. R.C. Bradley and M. Peligrad, Invariance principles under a two-part mixing assumption, Center for Stochastic Processes Technical Report, in preparation.

RUDOLF BRIGOLA

Dr. Brigola visited the Center with the express purpose of learning stochastic filtering theory. He studied with Kallianpur and held private discussions and seminars on this subject.

HARRY COHN

Dr. Cohn continued his work on the asymptotic behaviour of stochastic monotone Markov processes, and completed the following report.

Limit behaviour for stochastic monotonicity and applications [1]

A transition probability function P is said to be stochastically monotone if $P(x,(-\infty,y])$ is non-increasing in x for every fixed y. A (non-homogeneous) Markov chain or process is said to be stochastically moonotone if its transition probability functions are stochastically monotone. Diffusions, random walks, birth-and-death and branching processes are examples of such models. It is shown that stochastically monotone processes exhibit two basic types of asymptotic behaviour. Chains with stationary transition probabilties display a cyclic pattern, and a suitably normed and centered chain turns out to converge almost surely if it is geometrically growing. Applications to diffusions and branching processes are added.

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1. H. Cohn, Limit behaviour for stochastic monotonicity and applications, Center for Stochastic Processes Technical Report No. 93, Feb. 85.

THAD DANKEL

Dr. Dankel continued his work related to stochastic processes in underwater acoustics and a report is forthcoming.

He interacted with Kallianpur in the study of problems in infinite-dimensional stochastic differential equations. (As Kallianpur pointed out) Dankel's work on the stochastic mechanical interpretation of acoustic pulse propagation seems to have some technical similarity with recent work of Dawson and Papanicolaou on propagation in random media and Dankel has been investigating this aspect.

PETER HALL

Dr. Hall's research was in the diverse areas of nonparametric density estimation and bootstrapping methods. In density estimation, he and Dr. Marron computed the rate of convergence to the optimization of the cross-validated bandwidth for kernel estimators [1], and then showed that the obtained rate is best possible [2]. In his study of bootstrapping, he established a link between bootstrapping and an unconditional Edgeworth type expansion of the coverage probabilities of confidence intervals for a broad class of commonly used statistics in [3], and established results on the required number of bootstrap simulations in [4].

1. <u>The amount of noise inherent in bandwidth selection for a kernel density estimator</u> [1]

Let $f(.|h)$ be a kernel estimator of a density f, using bandwidth h. The bandwidth $\hat{h}_f$ which minimises the integrated square error of $\hat{f}$, depends on the unknown f. Therefore it is not a practical choice. Any data-driven attempt to minimise integrated square error must employ a bandwidth $\hat{h}$ which depends only on the sample. The integrated square error using $\hat{h}$ will exceed that using $\hat{h}_f$. In this paper we show that there is an unbridgeable gap between these two integrated square errors. In fact, we quantify the amount of noise inherent in any data-driven attempt to estimate $\hat{h}_f$. A bandwidth which minimises this noise might be called "second-order optimal". We show that the cross-validatory bandwidth <u>is</u> second-order optimal.

2. <u>Extent to which least-squares cross-validation minimises integrated square error in nonparametric density estimation</u> [2]

Let h_o, $\hat{h}_o$ and $\hat{h}_c$ be the windows which minimise mean integrated square error, integrated square error and the least-square cross-validatory criterion,

respectively, for kernel density estimates. It is argued that $\hat{h}_o$, not h_o, should be the benchmark for comparing different data-driven approaches to the determination of window size. Asymptotic properties of $h_o-\hat{h}_o$ and $\hat{h}_c - \hat{h}_o$, and of differences between integrated square errors evaluated at these windows, are derived. It is shown that in comparison to the benchmark $\hat{h}_o$, the observable window $\hat{h}_c$ performs as well as the so-called "optimal" but unattainable window h_o, to both first and second order.

3. <u>On the bootstrap and confidence intervals</u> [3]

We derive an explicit formual for the first term in an unconditional Edgeworth-type expansion of coverage probability for the nonparametric bootstrap technique applied to a very broad class of "studentized" statistics. The class includes sample mean, k-sample mean, sample correlation coefficient, maximum likelihood estimators expressible as functions of vector means, etc. We suggest that the boostrap is really an *empiric* one-term Edgeworth inversion, with the bootstrap simulations implicitly estimating the first term in an Edgeworth expansion. This view of the bootstrap is reinforced by our discussion of the iterated bootstrap, which inverts an Edgeworth expansion to arbitrary order by simulating simulations.

4. <u>On the number of bootstrap simulations required to construct a confidence interval</u> [4]

We make two points about the number, B, of bootstrap simulations needed to construct a percentile-t confidence interval based on an n-sample from a continuous distribution: (i) The bootstrap's reduction of error of coverage probability, from $O(n^{-1/2})$ to $O(n^{-1})$, is available <u>uniformly</u> in B, provided nominal coverage probability is a multiple of $(B+1)^{-1}$. In fact, this improvement is available even if the number of simulations is held fixed as n increases. (ii) In a large sample, the simulated statistic values behave like random observations

from a <u>continuous</u> distribution, unless B increases faster than any power of sample size. Only if B increases exponentially quickly is there a detectable effect due to discreteness of the bootstrap statistic.

<u>References</u>

1. P. Hall and J.S. Marron, The amount of noise inherent in bandwidth selection for a kernel density estimator, Center for Stochastic Processes Technical Report No. 100, May 85.

2. P. Hall and J.S. Marron, Extent to which least-squares cross-validation minimises integrated square error in nonparametric density estimation, Center for Stochastic Processes Technical Report No. 94, Feb. 85.

3. P. Hall, On the bootstrap and confidence intervals, Inst. of Statistics Mimeo Series No. 1574, Feb. 85.

4. P. Hall, On the number of bootstrap simulations required to construct a confidence interval, Center for Stochastic Processes Technical Report No. 97, Mar. 85.

TAILEN HSING

Significant contract activity has been devoted to extremal theory for stationary sequences and to aspects of point process structural theory. In his work here, Dr. Hsing has considered a combination of these areas, studying point processes related to extremal properties.

A general description and study of the point processes involved is given in [1]. These especially concern (a) exceedance point processes formed from process values above a high level and (b) two dimensional point processes obtained from normalization of both time and the values of a stochastic sequence. The exceedance point process under (a) provides a means of discussing asymptotic properties of specific extreme order statistics, whereas that in (b) gives a summary description for all joint asymptotic extremal distributions.

Exceedance point processes are studied in [2] (with M.R. Leadbetter) where cases of high dependence, leading to exceedance clustering, are considered and the possible limiting point processes determined. A corresponding treatment of the two dimensional point processes has been prepared and will be reported in [3].

A further topic considered concerns the extremal behavior of multivariate stochastic sequences - the results of this investigation will be reported in [4].

References

1. T. Hsing, Point processes associated with extreme value theory, Center for Stochastic Processes Technical Report No. 83, Dec. 84.

2. T. Hsing and M.R. Leadbetter, On the exceedance point process for a stationary sequence, Center for Stochastic Processes Technical Report No. 89, Jan. 85.

3. T. Hsing, On the weak limit of certain point processes generated by a stationary sequence, Center for Stochastic Processes Technical Report, in preparation.

4. T. Hsing, Extreme value theory for multivariate stationary sequences, Center for Stochastic Processes Technical Report, in preparation.

R. JAJTE

Dr. Jajte expanded his work in [1] reported earlier, into a monograph on non-commutative probability with applications to ergodic theory and quantum field theory [2].

References

1. R. Jajte, A non-commutative quasi-subadditive ergodic theorem, Center for Stochastic Processes Technical Report No. 73, Aug. 84.

2. R. Jajte, Strong limit theorems in non-commutative probability, Lecture Notes in Mathematics No. 1110, Springer, 1985.

Z.J. JUREK

Dr. Jurek continued his study of the connection between the limit laws of classical probabilty and the theory of stochastic processes, by representing the former as the laws of certain random integrals. The following reports were completed.

1. Continuity of certain random integral mappings and the uniform integrability of infinitely divisible measures [1]

It is shown that the class L(Q) of limiting distributions of appropriately normalitized partial sums of independent random variables which generalizes the classical Lévy class L, and which coincides with the laws of certain stochastic integrals of stationary, independent increments processes, is homeomorphic with the class $\mathrm{ID}_{\log}$ of all infinitely divisible probability measures having finite logarithmic moment. As an application of this result a set of generators of the entire class L(Q) is described. As a necessary tool, the relationship between the uniform integrability of infinitely divisible measures and of their corresponding Lévy measures is studied, which is of independent interest.

2. Random integral representations for classes of limit distributions similar to Lévy class L_0 [2]

For a linear operator Q, on a Banach space E, and a real number ß, there are introduced classes, $U_\beta(Q)$, of some limit distributions such that $U_0(I)$ coincides with the Lévy class L_0. Elements from $U_\beta(Q)$ are characterized in terms of convolution equations and as probability distributions of some random integral functionals. The continuity and fixed points of this random mapping are studied, and it is shown that its fixed points coincide with the class of Q-stable measures.

References

1. Z.J. Jurek and J. Rosinski, Continuity of certain random integral mappings and the uniform integrability of infinitely divisible measures, Center for Stochastic Processes Technical Report No. 95, Mar. 85.

2. Z.J. Jurek, Random integral representations for classes of limit distributions similar to Lévy class L_0, Center for Stochastic Processes Technical Report No. 117, Sept. 85.

H. KOREZLIOGLU

Dr. Korezlioglu completed a report on representations by means of stochastic integrals of distribution valued martingales, and worked on the approximation of the Zakai equation in nonlinear filtering by finite difference equations.

Stochastic integration for operator valued processes on Hilbert spaces and on nuclear spaces [1]

The representation of a nuclear space valued square integrable martingale in terms of another nuclear space valued square integrable martingale is given in terms of stochastic integrals of operator valued processes. The construction of the stochastic integral goes through that of operator valued processes on Hilbert spaces. A new approach is given for the Hilbertian case, so that only the integration of Hilbert-Schmidt operator valued processes is needed for the representation of square integrable martingales.

References

1. H. Korezlioglu and C. Martias, Stochastic integration for operator valued processes on Hilbert spaces and on nuclear spaces, Center for Stochastic Processes Technical Report No. 85, Dec. 85.

PETER KOTELENEZ

Dr. Kotelenez worked on stochastic differential equation models of chemical kinetic problems and completed the following report. The nuclear space valued stochastic differential equations obtained are linear and he also worked on extensions of his theory to make it applicable to more realistic situations and a report is forthcoming.

Fluctuations near homogeneous states of chemical reactions with diffusion [1]

Conditions are given under which a space-time jump Markov process describing the stochastic model of nonlinear chemical reactions with diffusion converges to the homogeneous state solution of the corresponding reaction-diffusion equation. The deviation is measured by a central limit theorem. This limit is a distribution valued Ornstein-Uhlenbeck process and can be represented as the mild solution of a certain stochastic partial differential equation.

References

1. P. Kotelenez, Fluctuations near homogeneous states of chemical reactions with diffusion, Center for Stochastic Processes Technical Report No. 122, Nov. 85.

A.G. MIAMEE

Dr. Miamee continued his work on the prediction of multivariate stationary signals and stationary random fields, completing the following reports.

1. Extension of three theorems of Fourier series on the disc to the torus [1]

Three well-known facts of Fourier series on the disc are extended to Fourier series on the torus: a theorem of Riesz, a theorem of Szegö, and the fact that any function in H^1 can be factored as the product of two functions in H^2. Here the role of negative integers is played by the lattice points in the third quadrant. In earlier extensions of these theorems this role was played by half-planes. These results are relevant in prediction of stationary random fields.

2. On the angle for stationary random fields [2]

This is described under the heading of Dr. Niemi.

3. On determining the predictor of non-full-rank multivariate stationary random processes [3]

Algorithms for determining the generating function and the predictor for some non-full-rank multivariate stationary stochastic processes are obtained. In fact it is shown that the well known algorithms given by Wiener and Masani (1958) for the full-rank case, are valid in certain non-full rank cases exactly in the same form.

4. Degenerate multivariate stationary processes: Basicity, past and future, and autoregressive representation [4]

Let $\{X_n\}$ be a not necessarily full rank multivariate weakly stationary stochastic process. It is shown that $\{X_n\}$ forms a generalized Schauder basis for the time domain of the process if and only if the angle between its past-present and future subspaces is positive. The validity of the autoregressive representation of $\{X_n\}$ and of its predictor are considered and some

characterizations for these representations are given. Under the additional assumption that the range of the spectral density f of a degenerate process $\{X_n\}$ is constant, some more concrete criteria for the validity of these representations are obtained.

5. On prediction of harmonizable stable processes [5]

This is described in item 2 under the heading of Cambanis.

6. Second order stationary random fields [6]

This is described in item 6 under the heading of Kallianpur.

References

1. A.G. Miamee, Extension of three theorems of Fourier series on the disc to the torus, Center for Stochastic Processes Technical Report No. 84, Dec. 84.

2. A.G. Miamee and H. Niemi, On the angle for stationary random fields, Center for Stochastic Processes Technical Report No. 92, Apr. 85.

3. A.G. Miamee, On determining the predictor of non-full-rank multivariate stataionary random processes, Center for Stochastic Processes Technical Report No. 96, Mar. 85.

4. A.G. Miamee and M. Pourahmadi, Degenerate multivariate stationary processes: basicity, past and future, and autoregressive representation, Center for Stochastic Processes Technical Report No. 99, May 85.

5. S. Cambanis and A.G. Miamee, On prediction of harmonizable stable processes, July 85.

6. G. Kallianpur, A.G. Miamee and H. Niemi, Spectral analysis of weakly stationary random fields: Moving average representations, in preparation.

HANNU NIEMI

Dr. Niemi worked on prediction problems for random fields related to the various "pasts" and "futures" that are possible in this case.

1. On the angle for stationary random fields [1]

The angle between past and future for stationary random fields on the lattice points of the plane is defined and it is shown that in contrast with other problems related to the past of random fields the positivity of the angle between past and future is independent of the different pasts which have been considered. Most of the known facts concerning the angle for stochastic processes have been extended to the case of random fields.

2. Second order stationary fields [2]

This is described in item 4 under the heading of Kallianpur.

References

1. A.G. Miamee and H. Niemi, On the angle for stationary random fields, Center for Stochastic Processes Technical Report No. 92, Apr. 85.

2. G. Kallianpur, A.G. Miamee and H. Niemi, Spectral analysis of weakly stationary random fields: Moving average representations, in preparation.

S. RAMASUBRAMANIAN

Dr. Ramasubramanian studied diffusion processes in the closed half plane and completed the report [1] described below. He has also been working jointly with Kallianpur on the study of discontinuous nuclear space valued stochastic differential equations. Specifically the case of Poisson random measures has been solved and further work is continuing [2]. A more detailed description is in item 2(b) under the heading of Kallianpur.

Hitting a boundary point by diffusions in the closed half space [1]

It is proved that a nondegenerate diffusion process in the closed half space $G = \{x \in R^d : x_1 \geq 0\}$, where $d \geq 2$, with Wentzell's boundary conditions does not hit any specified point on the boundary.

References

1. S. Ramasubramanian, Hitting a boundary point by diffusions in the closed half space, Center for Stochastic Processes Technical Report No. 108, June 85.

2. G. Kallianpur and S. Ramasubramanian, Weak convergence of Poisson driven stochastic differential equations with applications to nonlinear neuronal models, in preparation.

HOLGER ROOTZEN

Dr. Rootzén collaborated with M.R. Leadbetter, during a shorter visit. His work involved a study of various aspects of extremal theory - especially focussing on Markov sequences. A technical report on this work is being planned, and it will also be contained in a special invited paper (with M.R. Leadbetter) being proposed for the Annals of Probability.

JAN ROSINSKI

Dr. Rosinski pursued his research in the areas of stochastic integration and stable processes, and completed the following reports.

1. Moment inequalities for real and vector p-stable stochastic integrals [1]

   This is described under the heading of Dr. Woyczynski.

2. On stochastic integral representation of stable processes with sample paths in Banach spaces [2]

   Certain path properties of a symmetric stable process $X(t) = \int_S h(t,s)\, dM(s)$, $t \in T$, are studied in terms of the kernel h. The existence of an appropriate modification of the kernel h enables one to use results from stable measures on Banach spaces in studying X. Bounds for the moments of the norm of sample paths of X are obtained. This yiedls definite bounds for the moments of a double stable integral. Also necessary and sufficient conditions for the absolute continuity of sample paths of X are given. Along with the above stochastic integral representation of stable processes, the representation of stable random vectors due to LePage, Woodrooffe and Zinn is extensively used and the relationship between these two representations is discussed.

3. Continuity of certain random integral mappings and the uniform integrability of infinitely divisible measures [3]

   This is described under the heading of Dr. Jurek.

4. On stochastic integration by series of Wiener integrals [4]

   Stochastic integrals of random functions with respect to a white noise random measure are defined in terms of random series of usual Wiener integrals. Conditions for the existence of such integrals are obtained in terms of the nuclearity of certain operators on L^2-spaces. The relation with the Fisk-Stratonovich symmetric integral is also discussed.

References

1. J. Rosinski and W.A. Woyczynski, Moment inequalities for real and vector p-stable stochastic integrals, Center for Stochastic Processes Technical Report No. 87, Dec. 84.

2. J. Rosinski, On stochastic integral representation of stable processes with sample paths in Banach spaces, Center for Stochastic Processes Technical Report No. 88, Jan. 85.

3. Z.J. Jurek and J. Rosinski, Continuity of certain random integral mappings and the uniform integrability of infinitely divisible measures, Center for Stochastic Processes Technical Report No. 95, Mar. 85.

4. J. Rosinski, On stochastic integration by series of Wiener integrals, Center for Stochastic Processes Technical Report No. 112, Aug. 85.

JOZEF L. TEUGELS

Dr. Teugels (on a shorter visit) conducted research in an area involving basic tools of probability and stochastic process theory - that of the use of integral transforms. In particular this work provides inversion formulae for so-called Laplace and Stieltjes Transforms by using probabilistic rather than the usual means of complex analysis. The results of the work are reported in [1].

References

1. J.L. Teugels, Real inversion formulas for Laplace and Stieltjes transforms, Center for Stochastic Processes Technical Report No. 111, July 85.

A.S. USTUNEL

Ustunel worked in two areas:

(1) extending and applying Malliavin calculus to obtain generalizations of the Ito formula;

(2) exploring the relationship between Malliavin's calculus and Hida's theory of generalized Brownian motion.

Progress has been made in problem (1) and a report will soon be published. Ustunel and Kallianpur also discussed the problem of applying these techniques to Feynman integrals.

W.A. WOYCZYNSKI

Dr. Woyczynski pursued jointly with Dr. Rosinski their joint work on single and double integrals of stable processes.

Moment inequalities for real and vector p-stable stochastic integrals [1]

We obtain inequalities on the moments of single and double stochastic integrals with respect to stable motion. The proofs are based on our own work on the structure of single and multiple stable integrals, and on an appropriate modification of the work of R.F. Bass and M. Cranston (Ann. Probability, 1983, 578-588) on inequalities for moments of exit times of a stable motion. Also an extension is made to integrals of a vector-valued stable motion.

References

1. J. Rosinski and W.A. Woyczynski, Moment inequalities for real and vector p-stable stochastic integrals, Center for Stochastic Processes Technical Report No. 87, Dec. 84.

RESEARCH IN STATISTICAL ESTIMATION AND INFERENCE

RAYMOND J. CARROLL

Throughout the past year we have continued our work in three basic problem areas: data transformation, weighting least squares and measurement error models. Dr. Douglas Simpson completed his Ph.D. thesis under my direction in September, 1985, working on the topic of robustness for discrete data. Ms. Marie Davidian has made substantial progress towards finishing her thesis on the topic of variance function estimation. Ms. E. Kettl is working on combining data transformation and weighted least squares methods.

1. Optimally Bounded Score Functions for Generalized Linear Models with Applications to Logistic Regression (with L.A. Stefanski and D. Ruppert).

This is a very substantial revision of Mimeo Series #1554.

We study optimally bounded score functions for estimating regression parameters in a generalized linear model. Our work extends results obtained by Krasker & Welsch (1982) for the linear model and provides a simple proof of Krasker & Welsch's first order condition for strong optimality. The application of these results to logistic regression is studied in some detail with an example given comparing the bounded influence estimator with maximum likelihood.

2. Conditional Survival Models for Transient State Survival Analysis (with R.D. Abbott).

Survival models are important tools for the analysis of data when a disease event occurs with time and subjects are lost to follow-up. Many models, however, can also be adapted for use when an event is characterized by transitions through intermediate states of disease with increasing severity. In this presentation, such an adaptation will be demonstrated for a class of conditional regression models for the analysis of transient state events occurring among grouped event times. The type of conditioning that will be described is useful in providing

comparisons of specific disease states and an assessment of transition dependent risk factor effects. An example will be given based on the Framingham Heart Study.

3. <u>A Note on some Simple Influence Diagnostics in Accelerated Life Testing</u> (with H. Schneider and L. Weissfeld).

Three methods for assessing influence in an accelerated life-testing model are considered; two different one-step approximations to the estimated parameter after case deletion and a method which treats extreme values at each design point as censored. These methods are compared using an example. Problems which occur when all observations at a design point are censored are discussed.

4. <u>A Note on the Effect of Estimating Weights in Weighted Least Squares</u> (with D. Ruppert)

We consider fitting a linear model to data which exhibits nonconstant variance or heteroscedasticity. The model we assume is that the variances are a function of known explanatory variables and an unknown parameter θ. It turns out that first order asymptotic theory suggests that the resulting extended least squares estimates based on estimating the unknown paramater θ has approximately the same distribution that would be obtained if θ were known. In some circumstances, this first order asymptotic result is quite optimistic and there can be a substantial cost to having to estimate θ. We calculate the variance of the extended least squares estimate with estimated θ to order $1/N^2$, thus delineating circumstances where the first order asymptotics are optimistic and a bootstrap procedure would be warranted. A small simulation backs up the theoretical results. Our results also indicate the effect of preliminary estimators.

5. <u>Some New Estimation Methods for Weighted Regression when there are Possible Outliers</u> (with D.M. Giltinan and D. Ruppert).

The problem of estimating the variance parameter robustly in a heteroscedatic

linear model is considered. The situation where the variance is a function of the explanatory variables is treated. To estimate the variance robustly in this case, it is necessary to guard against the influence of outliers in the design as well as outliers in the response. By analogy with the homoscedastic regression case, two estimators are proposed which do this. Their performance is evaluated on a number of data sets. We had considereable success with estimators that bound the "self-influence", that is, the influence an observation has on its own fitted value. We conjecture that in other situations, for example, homoscedastic regression, bounding the self-influence will lead the estimators with good robustness properties.

6. The Limiting Distribution of Least Squares in an Errors-in-variables Linear Regression Model (with L.J. Gleser and P.P. Gallo).

It is well-known that the ordinary least squares (OLS) estimator $\hat{\beta}$ of the slope and interept parameters β in a linear regression model with errors of measurement for some of the independent variables (predictors) is inconsistent. However, Gallo (1982) has shown that certain linear combinations of β are consistently estimated by the corresponding linear combinations of $\hat{\beta}$. In this paper, it is shown that under reasonable regularity conditions such linear combinations are (jointly) asymptotically normally distributed. Some methodological consequences of our results are given in a companion paper (Carroll, Gallo and Gleser, 1985).

7. Data Transformation in Regression Analysis with Applications to Stock-Recruitment Relationships (with D. Ruppert).

We consider a problem in nonlinear regression modelling which has applications to fields as diverse as chemical kinetics, biological and chemical assays and stock-recruitment relationships in marine biology. In many such problems, the variability of the responses can be modelled as a function of the

mean response. Additionally, we often observe significant skewness. Two types of transformations, power transformation and weighting, are used together to remove skewness and to induce constant variance. Our method is applied to the stock-recruitment data of four fish stocks. Also discussed are estimates of the conditional mean and the conditional quantiles of the original response.

8. A Note on the Effect of Ignoring Small Measurement Errors in Precision Instrument Calibration (with C.H. Spiegelman).

Our focus is the simple linear regression model with measurement errors in both variables. It is often stated that if the measurement error in x is "small", then we can ignore this error and fit the model to data using ordinary least squares. There is some ambiguity in the statistical literature concerning the exact meaning of a "small" error. For example, Draper and Smith (1981) state that if the measurement error variance in x is small relative to the variability of the true x's, then "errors in the x's can be effectively ignored", see Montgomery & Peck (1983) for a similar statement. Scheffe (1973) and Mandel (1984) argue for a second criterion, which may be informally summarized that the error in x should be small relative to (the standard deviation of the observed Y about the line)/(slope of the line). We argue that for calibration experiments both criteria are useful and important, the former for estimation of x given Y and the latter for confidence intervals for x given Y.

References

1. L.A. Stefanski, R.J. Carroll and D. Ruppert, Bounding influence and leverage in logistic regression, Institute of Statistics Mimeo Series No. 1554, August 1984.

2. R.D. Abbott & R.J. Carroll, Conditional regression models for transient state survival analysis, Institute of Statistics Mimeo Series No. 1555.

3. H. Schneider & L. Weissfeld & R.J. Carroll, A note on some simple influence diagnostics in accelerated life testing, Institute of Statistics Mimeo Series No. 1562.

4. R.J. Carroll & D. Ruppert, A note of the effect weights in weighted least squares, Institute of Statistics Mimeo Series No. 1570.

5. D.M. Giltinan, R.J. Carroll & D. Ruppert, Some new estimation methods for weighted regression when there are possible outliers, Institute of Statistics Mimeo Series No. 1571.

6. L.J. Gleser, R.J. Carroll & P.P. Gallo, The limiting distribution of least squares in an errors-in-variables linear regression model, Institute of Statistics Mimeo Series No. 1577.

7. D. Ruppert & R.J. Carroll, Data transformations in regression analysis with appliations to stock - recruitment relationships, Institute of Statistics Mimeo Series No. 1578.

8. R.J. Carroll & C.H. Spiegelman, A note on the effect of ignoring small measurement errors in precision instrument calibration, Institute of Statistics Mimeo Series No. 1580.

WOLFGANG HÄRDLE

Dr. Härdle studied robustness aspects of procedures for selection of regression variables [1], and the rate of convergence of various automatically selected bandwidths in kernel regression estimation [2].

1. An effective selection of regression variables when the error distribution is incorrectly specified [1]

In the situation where the statistician estimates regression parameters by maximum likelihood methods but fails to choose a likelihood function matching the true error distribution, an asymptotically efficient selection of regression variables is considered. The proposed procedure is especially useful when a robust regression is applied but the data in fact do not require that treatment. Examples are given and relationships to other selectors such as Mallows' C_p are investigated.

2. How far are automatically chosen regression smoothing parameters from their optimum? [2]

In the setting of nonparametric curve estimation the problem of smoothing parameter selection is addressed. The deviation between the optimal bandwidth and the bandwidths provided by a number of automatic selection methods is studied both theoretically and by simulation. The theoretical results include a central limit theorem which shows both the rate of convergence and the asymptotic distribution of the deviation. The simulations show that the asymptotic normality describes the distribution quite well for surprisingly small samples.

References

1. W. Härdle, An effective selection of regression variables when the error distribution is incorrectly specified, Institute of Statistics Mimeo Series No. 1582, Sept. 85.

2. W. Härdle, P. Hall and S. Marron, How far are automatically chosen regression smoothing parameters from their optimum?, Institute of Statistics Mimeo Series Technical Report, in preparation.

STOCHASTIC PROCESSES SEMINARS

Sept. 5	Randomized system trajectories, W.L. Root, University of Michigan.
Sept. 26	Generalized semi Markov processes and insensitivity, Francois Bacelli, INRIA, Paris
Oct.11&12	Statistics of processes of semimartingale type, A.N. Shiryaev, Steklov Institute of Mathematics.
Oct. 24	Stochastic integration for operator valued processes on Hilbert spaces and on nuclear spaces, H. Korezlioglu, CNET, Paris
Oct. 31	Strong limit theorems in von Neumann algebras, R. Jajte, University of Lodz.
Nov. 5	A test for shifts in the distribution based on the locations of the extremes, Y. Mittal, VPI & State University.
Nov. 14	What do stable distributions have to do with the Xerox machine and statistical physics?, A. Weron, Technical University of Wroclaw.
Nov. 26	Conditional limit theorems and Brownian excursions, J.-P. Imhof, University of Geneva.
Nov. 28	On the range of Brownian motion and its inverse process, J.-P. Imhof, University of Geneva.
Nov. 29	Ergodic theory and dynamical systems, G. Kallianpur, University of North Carolina.
Dec. 5	Prediction properties of discrete stationary random fields, H. Niemi, University of Helsinki.
Jan. 16	Stochastic integral and series representations of stable processes, J. Rosinski, University of Wroclaw.
Jan. 23	A survey of classic central limit theorems under strong mixing conditions, R.C. Bradley, Indiana University.
Jan. 29	Branching processes with infinite mean, H. Cohn, University of Melbourne.
Jan. 31	Counterexamples to the central limit theorem under strong mixing conditions, R.C. Bradley, Indiana University.
Feb. 6	On the angle for stationary random fields, A.G. Miamee, Isfahan University of Technology.
Feb. 13	A martingale characertization of the conditional distribution in nonlinear filtering, D. Ocone, Rutgers University.

Feb. 20	Limit behaviour for stochastic monotonicity and applications, H. Cohn, University of Melbourne.
Feb. 25	Edgeworth expansions, confidence intervals and the bootstrap, P. Hall, Australian National University.
Feb. 27	Quadratic variation and energy, M. Rao, University of Florida.
Mar. 13	How many balls can you pack on a transient Brownian path?, S.J. Taylor, University of Virginia.
Mar. 14	Records from improving populations, S. Resnick, Colorado State University.
Mar. 27	CLT for diffusions with almost periodic coefficients, S. Ramasubramanian, Center for Stochastic Processes.
Apr. 3	Random geometric patterns, P. Hall, Australian National University
Apr. 10	Stochastic mechanics and acoustic pulse propagation in the ocean, T. Dankel, UNC-Wilmington.
Apr. 12	Statistics and biosequences: some applications to molecular biology, D. Lipman, National Institute of A.D.D. & K. Diseases.
Apr. 17	Diffusions in reverse time, R.J. Elliott, University of Hull.
Apr. 23	Gaussian limit to reaction and diffusion systems, P. Kotelenez, University of Bremen.
Apr. 24	Some problems connected with Lévy's multiparameter Brownian motion, D. Wölzow, University of Erlangen-Nürnberg.
Apr. 30	Malliavin calculus, A. Ustunel, CNET, Paris.
June 12	On stochastic integration by series of Wiener integrals, J. Rosinski, University of Wroclaw.
June 19	A limitation of Markov representation for stationary processes, R.C. Bradley, Indiana University.
July 29	Local nondeterminism and local times of stable processes, J. Nolan, Kenyon College.
July 31	Some problems from insurance mathematics, J.L. Teugels, Katholieke Universität Leuven.
Aug. 16	Estimation for stochastic process regression models using the method of sieves, I. McKeague, Florida State University.
Aug.28	Classes of limit laws similar to the Lévy class L_0, Z.J. Jurek, Auburn University.

LIST OF PROFESSIONAL PERSONNEL

1. Faculty Investigators:

S. Cambanis
R.J. Carroll
G. Kallianpur
M.R. Leadbetter

2. Visitors

Senior:

R. Adler	Technion	Aug. 85 - present
R. Bradley	Indiana Univ.	Jan - June 85
H. Cohn	Univ. of Melbourne	Jan. - Feb. 85
R. Jajte	Lodz Univ.	Sept. - Dec. 84
Z.B. Jurek	Wroclaw Univ.	July - Aug. 84
A.H. Korezlioglu	E.N.S. Telecommunications	Sept. - Nov. 84
P. Kotelenez	Univ. of Bremen	Apr. 85
A.G. Miamee	Isfahan Univ. of Techn.	Sept. 84 - July 85
H. Niemi	Univ. of Helsinki	Sept. 84 - Jan. 85
H. Rootzén	Univ. of Copenhagen	Aug. 85
J. Teugels	Katholieke Univ. Leuven	June - July 85
W. Woyczynski	Case Western Reserve Univ.	Dec. 84

Junior:

R. Brigola	Univ. of Regensburg	Mar. -Apr. 85
T. Dankel	UNC-Wilmington	June 85
W. Härdle	Goethe Univ.	Aug. 85
T. Hsing	U. Texas at Arlington	May - Aug. 85
S. Ramasubramanian	Indian Statistical Inst.	Jan. - June 85
J. Rosinski	Univ. of Tennessee	Sept. 84 - Aug. 85
A.S. Ustunel	CNE Telecommunications	Apr. 85

3. Graduate Students:

S.K. Christensen
M. Davidian
H.P. Hucke
E. Kettl
M.S. Marques
V. Perez-Abreu

INTERACTIONS

S. Cambanis presented invited talks at the Fifth Aachen Colloquium on Mathematical Methods in Signal Processing in Aachen (Sept. 84), the SREB/ASA Summer Research Conference in Statistics in Boone (June 85), and the annual meeting of the Institute of Mathematical Statistics in Las Vegas (Aug. 85). He gave invited colloquium talks at: the Ecole Polytechnique in Paris, Johns Hopkins University, University of Wisconsin, and Northern Illinois University. He gave a talk at the International Symposium on Information Theory in Brighton (June 85). He also served as Editor of the SIAM Journal on Applied Mathematics, and Associate Editor for Stochastic Processes of the IEEE Transactions on Information Theory.

R.J. Carroll was Visiting Professor of Statistics at the Mathematics Research Center, Sept. - Dec. 84. He was an invited participant at the conference "Robust Statistics" in Oberwolfach (Sept. 84). Throughout the year, he was an Associate Editor of the Annals of Statistics and the Journal of the American Statistical Association, as well as a member of the Nati al Academy of Science Panel on Youth Employment. He presented invited talks at: Lilly Research Labs (Indianapolis, Indiana), Iowa State University, Purdue University, University of Minnesota, MIT, University of California at Davis, University of South Carolina, the ORSA-IMS annual meeting in Boston, and the Midwest Biopharmaceutical Statistics Workshop in Muncie, Indiana. He also presented tutorials on errors-in-variables methods to the National Cancer Institute, and on power transformations to the National Heart, Lung and Blood Institute.

G. Kallianpur gave plenary lectures at the International Conference on Modelling and Control in Kiev (Sept. 84), and the IFIP Conference on Filtering Theory in Rome (Dec. 84). He was an invited speaker at the Virginia Polytechnic Institute Lecture Series (March 85). He spoke at the International Symposium on

Probability and Statistics in Vilnius (June 85), the Bernoulli Society Conference on Stochastic Processes in Nagoya (July 85), and the Japan - U.S.A. seminar on Stochastic Methods in Biology in Nagoya (July 85). He gave series of lectures on filtering theory and the Feynman integral at Yonsei University and the Korean Advanced Institute of Science and Technology in Seoul (July 85), and on infinite dimensional stochastic differential equations at the University of Bergen (Aug. 85). He gave invited talks at the University of Oslo and the Indian Statistical Institute (May 85). He also served as Editor of Sankhya and as Associate Editor of the Journal of Multivariate Analysis, the Journal of Applied Mathematics and Optimization, and Stochastic Processes and Their Applications.

M.R. Leadbetter gave invited talks at the Pacific Congress and Australian Mathematical Society meetings in May 1985, and a seminar at the University of Kentucky. He completed his three year term on the Council of the Institute of Mathematical Statistics and represented the IMS on the American Mathematical Society committee for summer conferences. He also began a further term as Associate Editor for the Annals of Probability.

R. Bradley gave an invited talk at the conference on dependence in Oberwolfach (March 85).

H. Cohn gave an invited talk at the University of California, Davis.

P. Hall gave invited talks at: University of California at Berkeley, Stanford University and University of Wisconsin.

A. Miamee gave invited talks at the University of Pittsburgh, Michigan State University, and Northern Illinois University.

H. Niemi gave invited talks at the University of Pittsburgh, Michigan State University, and Northern Illinois University.

V. Perez-Abreu gave two invited talks at the Seminar on Multiple Stochastic Integrals and Polynomial Chaos at Case Western Reserve University (May 85).

J. Rosinski gave an invited talk at the Seminar on Multiple Stochastic Integrals and Polynomial Chaos at Case Western Reserve Univ. (May 85), a paper at the annual meeting of the American Mathematical Society in Anaheim (Jan. 85), and a colloquium talk at the University of Tennessee.

A. Ustunel gave colloquium talks at Purdue University and the University of Texas, Austin.

FINAL REPORT

1 November 1981 - 31 August 1985

SUMMARY OF RESEARCH ACTIVITY

Research in Stochastic Processes

Introduction

The research effort in stochastic processes was a major part of a substantial research activity organized as the Center for Stochastic Processes in the Statistics Department. This effort, involving permanent faculty, visitors and students, has developed in a very significant way under continuing AFOSR support. Indeed, building on the previously existing departmental capability, the stochastic process activities are attracting wide interest and recognition in the international statistical community. The main ingredients of the program are:

(i) Significant research interaction among the permanent faculty, the senior internationally recognized visitors, and the junior visitors - promising young researchers.

(ii) The weekly Stochastic Processes Seminar which provides a regular forum for exchange of current research ideas among permanent and visiting staff as well as short term visitors.

(iii) The Center for Stochastic Processes Technical Report series which contains the research produced by permanent and visiting staff, prior to publication in the scientific literature. To date 125 technical reports have been produced by the participants, involving research results in a wide area of stochastic process theory and applications.

Summary of Main Research Activities

Advances have been made in non-Gaussian signal processing with special reference to stable signals and robustness of the methods to mild departures from

normality. The problems of prediction, interpolation and nonparametric density estimation have been solved for harmonizable stable signals. The innovations structure of stable signals have been developed, and their ergodic properties established.

In the area of digital processing of analog signals very simple quantizers that are asymptotically optimal have been introduced, a new delayed delta modulator has been introduced and analysed, and the performance of an adaptive differential pulse code modulator has been analysed. Various sampling designs for correlated time series, along with their small and large sample performance have been studied for signal detection, prediction, and integral estimation with and without noise.

In the area of nonlinear signals and systems the stationarity and forecasting of doubly stochastic time series models has been studied, along with estimation in stationary and nonstationary nonlinear time series models. Multiple Wiener integrals and stochastic integrals of independent increments processes have been fully developed. Also quadratic functionals of stable motion have been characterized, and nonlinear functionals of infinite dimensional Wiener processes have been expanded into series of multiple Wiener integrals.

The new (finitely additive) white noise approach to nonlinear filtering has been substantially developed and extended to diffusion and Markov signal processes. It makes it unnecessary to solve stochastic differential equations (DE's) and stochastic partial DE's, and replaces them by "ordinary" partial DE's or integro-DE's, thereby establishing their robustness.

Stochastic differential equation (SDE) models have been extensively developed. Linear and nonlinear SDE's driven by infinite-dimensional Poisson and Ornstein-Uhlenbeck processes have been studied, along with the weak convergence of their solutions. Applications have been made to models for spatially extended

neurons in neurophysiology. Also diffusion approximations of the Boltzmann equation have been studied.

The prediction and extrapolation of stationary random fields has been studied, along with moving average representations, their four-fold Wold decomposition and their multiplicites, and time domain and spectral criteria for nondeterminism.

Analytical and sequential Feynman integrals have been defined and studied.

The work in extremal theory for stochastic sequences focused primarily on cases where high local dependence can occur in a stationary sequence leading to a theory for asymptotic distributions of extreme order statistics, which encompasses, but is significantly more general than classical extreme value theory.

These results are related (and indeed largely stem from) research which concerns properties of certain point processes associated with extremal theory. The primary emphasis concerned the so-called exceedance point process, defined by the instants of time at which the stationary sequence considered falls above a suitable given high level. Limiting distributional convergence results were obtained for this and other (e.g. two dimensional) point processes related to the extremal behavior of the underlying sequence.

A significant effort was also conducted into basic dependence structure in stochastic sequences, and various new relationships between different types of "mixing" assumptions were obtained. Such a basic study is important in determining the most appropriate type of dependence condition for application, e.g. in the work on extremal and point process structural theory.

In the area of function estimation for stationary sequences and processes estimation of probability densities was considered for both stationary sequences and continuous parameter processes, comprehensive results being obtained.

Research in Statistical estimation and inference

Advances in statistical methodology have been made in this contract period in three separate areas.

In the area of heteroscedastic or weighted regression, this period has seen the development of the pseudo-likelihood method of variance function estimation and the introduction of smoothing ideas into the literature; the former method has been adopted to Eli Lilly & Company for use in biochemical assays.

In the area of data transformation the transform-both-sides methodology has been introduced and has already been applied to kinetic reactions, finance and biology by other research workers.

In the area of measurement error models the idea of conditioning to estimate parameters in nonlinear models has been introduced; there is a group at the National Cancer Institute which is presently developing these ideas for routine use.

In the area of nonparametric density and regression function estimation the amount of noise inherent in bandwidth selection has been specified, and the mean integrated square error has been effectively approximated.

Ph.D. DEGREES AWARDED

P. Gallo:	Properties of estimators in error-in-variables regression models	Oct. 1981
J. Castellana:	Nonparametric estimation of probability densities for stationary sequences	Feb. 1982
N.L. Gerr:	Exact analysis of a delayed delta modulator and an adaptive differential pulse-code modulator	Oct. 1982
D. Gi!tinan:	Bounded influence estimation in heteroscedastic linear models	Nov. 1983
L. Stefanski:	Influence and measurement error in logistic regression	Nov. 1983
T. Hsing:	Point processes associated with extreme value theory	Aug. 1984
V. Perez-Abreu C.:	Product stochastic measures, multiple stochastic integrals and their extensions to nuclear space valued processes	Apr. 1985
S.K. Christensen:	Linear stochastic differential equations on the dual of a countably Hilbert nuclear space with applications to neurophysiology	June 1985
H.P. Hucke:	Estimation of continuous time Markov processes in in a finitely additive white noise model	Oct. 1985

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